Fifth Annual Conference on Carbon Capture & Sequestration

Steps Toward Deployment

Geologic – Monitoring, Mitigation, and Verification

A Statistical Algorithm to Detect and Quantify CO_2 Leakage for the Verification of Geologic Carbon Sequestration

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A Statistical Algorithm to Detect and Quantify Near-Surface CO_2 Leakage for Verification of Geologic Carbon Sequestration

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Motivation

- Monitoring of CO_2 storage sites must be carried out to verify that CO_2 is not leaking
- Meet challenge of detecting subtle leakage signals within background variability by…

Strategy

- Integrating near-surface measurements of CO_2 fluxes or concentrations with statistical algorithm that enhances properties of the data that are associated with leakage, while reducing random background contributions

Background vs. Leakage Signals: Differences

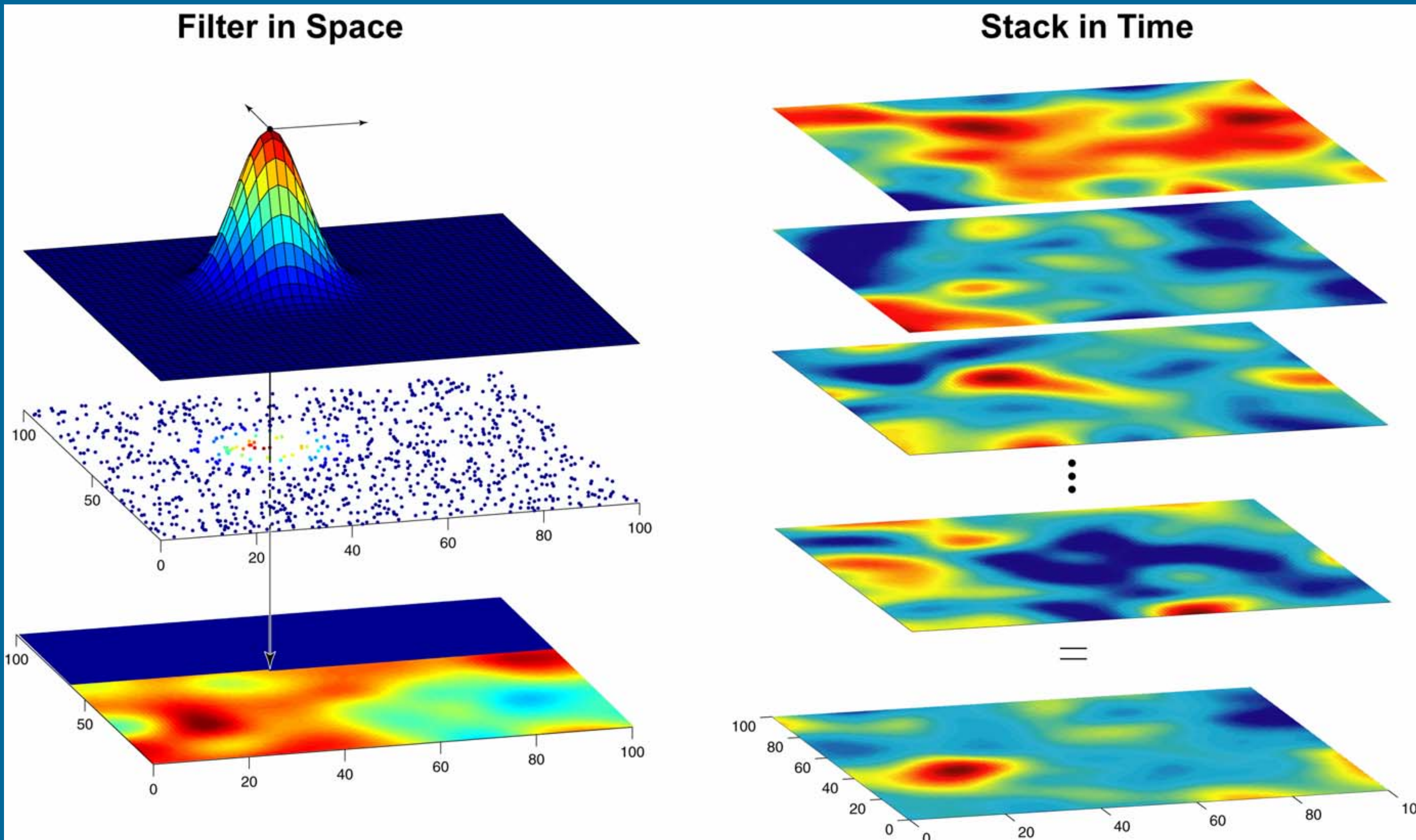
- High spatial heterogeneity of biological production
- Production correlated on predictable timescales

- Leakage (along well bore or fault) relatively coherent in space
- Leakage relatively constant

Background vs. Leakage Signals: Similarities

- Near-surface CO_2 fluxes/concentrations from both sources modified on predictable timescales
- These temporal variations can be removed from spatial flux/concentration datasets
- Areas of elevated spatial and temporal correlation in CO_2 associated with leakage can then be made more obvious

Filtering and Stacking Method



Surface CO_2 Flux Leakage Signals

- Two-dimensional scaled Gaussian distribution
- Modeled surface CO_2 fluxes associated with CO_2 leakage from well bore (point) and fault (line) sources using TOUGH2/T2CA

Background Surface CO_2 Fluxes

- Background biological noise added to leakage signal and surrounding area (10^6 m^2)
- Accumulation chamber method in grassland, central CA
- n = 287, 5-m spacing grid, uncorrelated on this scale
- Diurnal fluctuations removed, μ = 8.7 g $m^{-2}d^{-1}$ = F_B

Sampling and Processing Strategies

- Grid and random sampling strategies investigated
- In all cases, 100 fluxes sampled from the underlying synthetic data set during each repeat sampling campaign, Gaussian filtering applied to each of the repeat data sets, and fluxes temporally averaged at each interpolated grid point

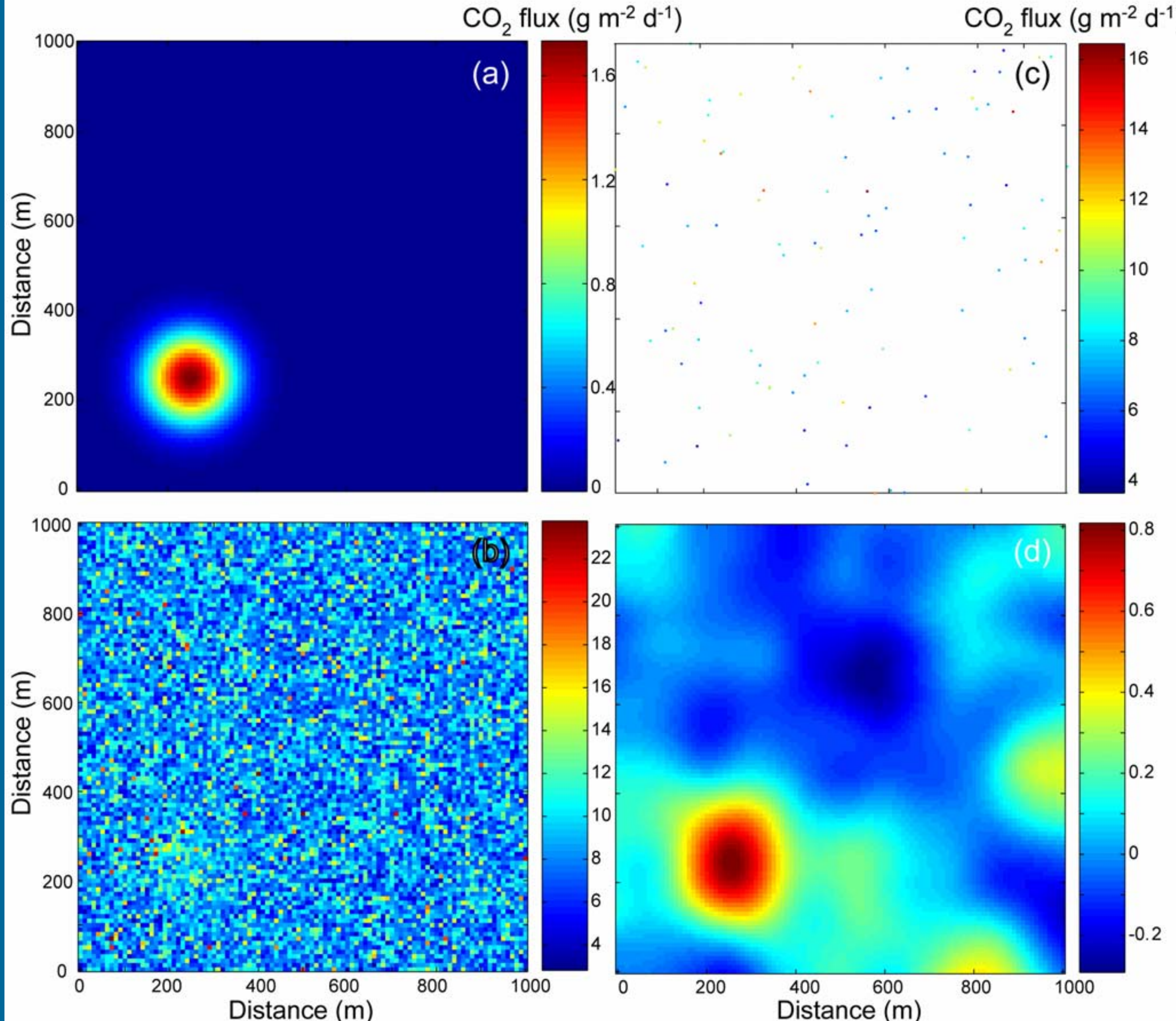
Strategy Success

$$f_{ME} = \sqrt{(LR_I - LR_C)^2} \;/\; LR_I$$

LR_I = Imposed leakage rate
LR_C = Calculated leakage rate

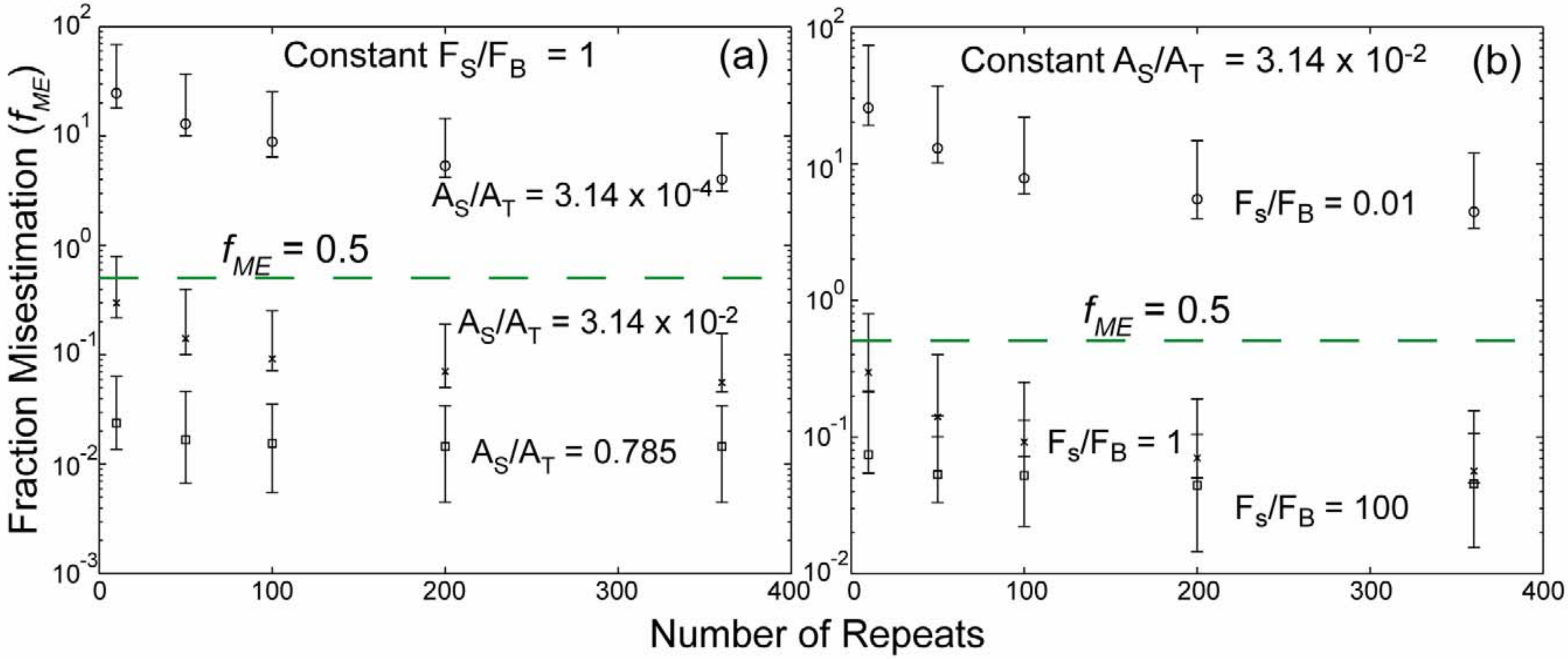
Leakage rate = spatially integrated flux of synthetic source

f_{ME} </= 0.5: "detectable" leakage signal
f_{ME} > 0.5: "undetectable"



F_B = average background flux = 8.7 g m^{-2}d^{-1}
F_S = maximum leakage flux = 1.7 g m^{-2}d^{-1}
R = Gaussian length scale = 100 m

f_{ME} = 0.02 for 100 repeat sampling campaigns



R = Gaussian length scale

L = model domain length = 1000 m

R/L = 0.01, 0.1, 0.5

F_B = average background flux = 8.7 g m^{-2} d^{-1}

A_S = area of synthetic source

A_T = area of model domain = 10^6 m^2

F_S = maximum leakage flux

$$f_{ME} = \sqrt{(LR_I - LR_C)^2} / LR_I$$

Conclusions

- Importance of maximizing A_S/A_T when F_S within the background variability of CO_2 flux or when A_S is small (e.g., wells, mostly sealed faults/fractures)
- Method applies to other gas species and concentrations
- 10 to 50 repeat sampling campaigns (100 samples each) reasonable within a year

Conclusions

- Assumptions of method
  - fluxes are statistically uniform over study area
  - leakage slowly evolving over period of observation
- Strategy provides means to locate and quantify potentially small CO_2 leakage signals within the natural background variability of CO_2

Acknowledgements

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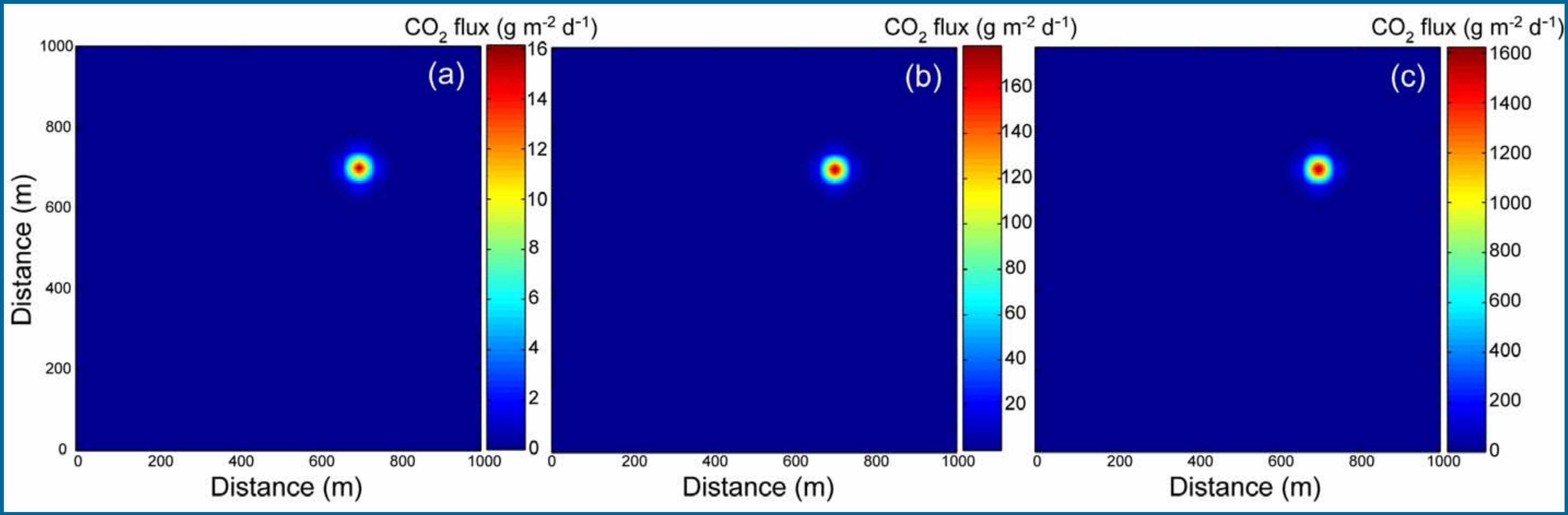
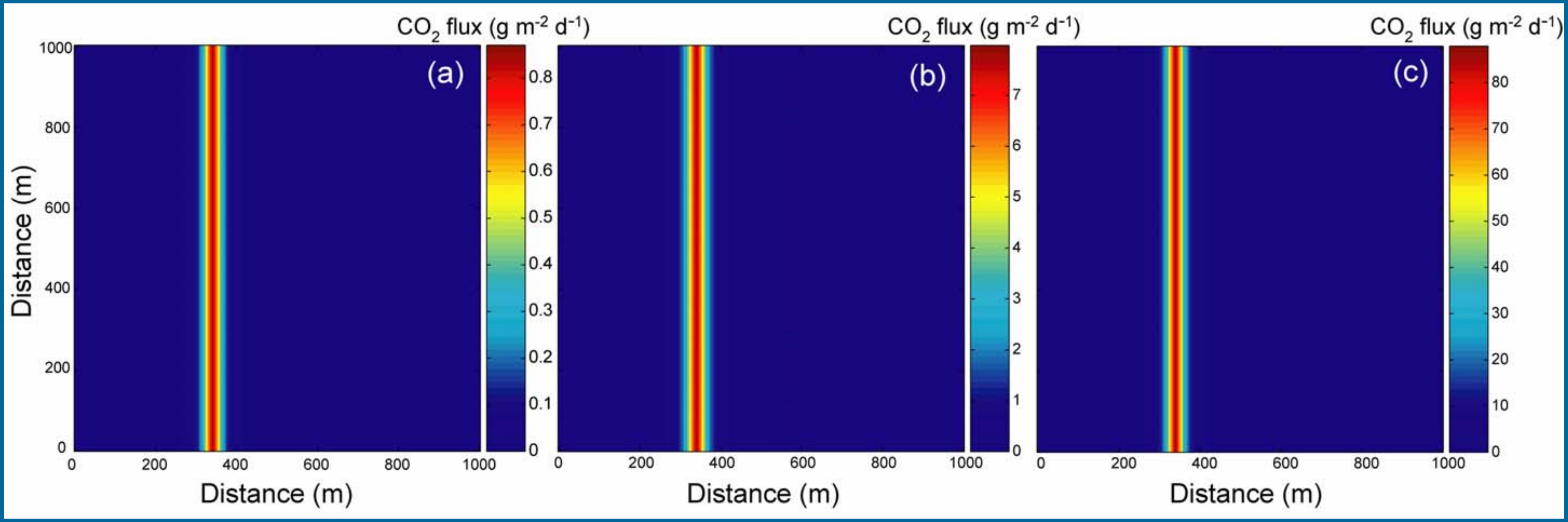
Vadose Zone Model

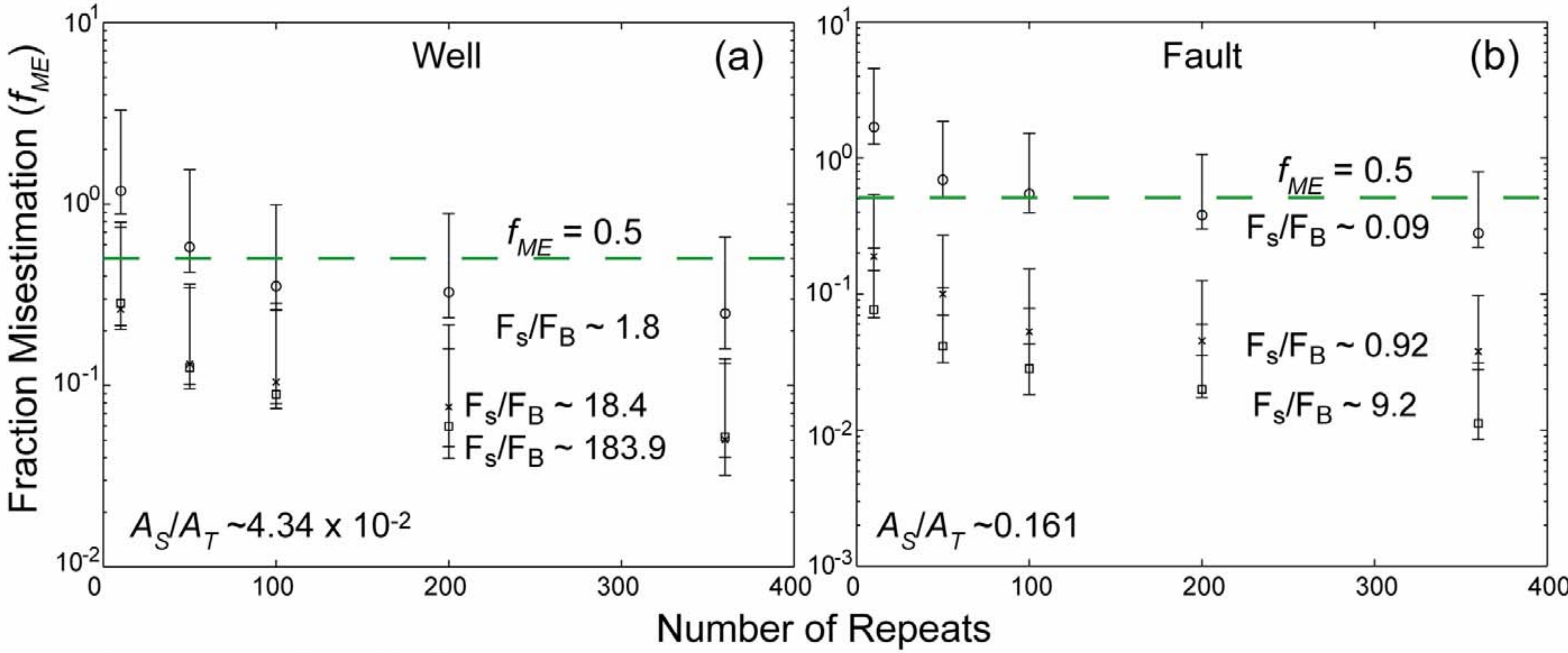
- **Subsurface:** 1000 m x 1000 m x 28 m, k = 1 x 10^{-12} m^2, n = 0.2 , T = 15^{o}C
- **Well** source geometry: 1 x 1 m, -27.1 m depth. Source leakage fluxes: 3.8 x 10^4, 3.8 x 10^5, 3.8 x 10^6 g $m^{-2}d^{-1}$
- **Fault** source geometry: 10 x 1000 m, -27.1 m depth. Source leakage fluxes: 3.8, 38, 380 g $m^{-2}d^{-1}$

Surface CO_2 Leakage Fluxes: Well Simulations



Surface CO_2 Leakage Fluxes: Fault Simulations





A_S = area of synthetic source

A_T = area of model domain = 10^6 m^2

F_S = maximum leakage flux

F_B = average background flux = 8.7 g m^{-2} d^{-1}

$$\boldsymbol{f_{ME} = \sqrt{(LR_I - LR_C)^2} \;/\; LR_I}$$